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TECHNICAL REPORT

Metal Concentrations in Sediments, and Selected Biota
from Mine Tailings in Gastineau Channel,
Juneau, Alaska

by:

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ABSTRACT

Title: Metal concentrations in sediments, and selected biota from mine tailings in Gastineau Channel, Juneau, Alaska

Abstract: Hardrock gold mining occurred in Juneau from 1880 to 1944. Tailings and waste rock from the mines were deposited into Gastineau Channel and formed beaches along parts of both Juneau and Douglas Island. Mining companies are proposing to reopen some former mines to recover residual gold. Cyanide-treated tailings will be pumped to an impoundment in a nearby mountain valley and an effluent outfall will be constructed in Gastineau Channel. Migratory salmonids, waterfowl, and shorebirds use the channel on a seasonal basis and bald eagles are year-round residents. This study determined concentrations of toxic metals in sediment and resident biota from the channel. Composite sediment samples were collected from 20 locations across and down the channel for an eight km distance. Fish and shrimp were collected by mid-channel trawl. Blue mussels and cockles were collected at low tide from six locations from an area composed of old tailings. Freshwater fish were taken from the former Treadwell Mine site on Douglas Island. Mean concentrations of arsenic, copper, lead, and zinc in sediments were higher than concentrations detected in sediments from other locations in southeast Alaska. Lowest concentrations in sediments were found near the mouth of the channel. Mean concentrations of lead, mercury, and zinc in Gastineau Channel were comparable to concentrations found in sediments from South Puget Sound, WA, an area with pollution problems. Tissue concentrations for whole fish from four species of bottom fish indicate that lead, arsenic, mercury, and zinc are elevated. Molluscs also had elevated concentrations of lead and zinc. Concentrations were comparable to those reported in mussels from Commencement Bay, WA, an area of industrial pollution. These data indicate that metal levels in Gastineau Channel are of concern in regards to environmental health and that the combination of tailings and present urban pollution has contributed to the current situation. Proposals for adding metals to the channel through permitted effluent should be carefully considered with respect to these data.

Key words: marine sediments, metals, fish, molluscs, mining

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INTRODUCTION

HISTORICAL BACKGROUND

The Juneau Gold Belt is an area of mineralized deposits that stretches over a hundred miles along the coast of southeast Alaska with Juneau the approximate center of the area. From 1880 when gold was first discovered in Juneau to 1944 when the last mine closed, \$158 million in gold was produced (Stone and Stone 1980). In Juneau there were three major mine areas, the Treadwell Complex, located on Douglas Island, the Alaska Gastineau Mine, located at Thane, about six km south of downtown Juneau, and the A-J Mine, located within Mt. Roberts. The mill for this mine is located above the old ferry terminal in downtown Juneau. The mining method used to extract ore from the surrounding mountains was through excavating tunnels and adits. Ore was reduced by crushing the material and treating the pulverized, concentrated ore with cyanide to remove gold and silver. Earlier mining operations at the Treadwell Complex amalgamated gold by passing the pulverized gold over inclined tables covered with a copper and zinc mercury plate.

Tailings and waste rock from the mines were either dumped by barge into Gastineau Channel or by train and conveyor belt to the waterfront. The Treadwell mine tailings created a 1200 m beach along Douglas Island. The Alaska Gastineau mine sent 12,000 tons of tailings per day to the beach near Thane. A total of 90 million tons of ore and rock were moved from the A-J mine from 1893 to 1944. Tailings were deposited without compaction and as a result often have a low density.

PRESENT CONDITIONS

The tailings from the A-J mine range in size from coarse gravel to silt and contain elevated amounts of barium, lead, zinc, cadmium, and arsenic (Ecology and Environment 1990). A 1987 study of A-J tailings found lead ranging from 69 to 226 ppm and zinc concentrations at 186 to 588 ppm (Golder Associates 1987). Rock dump (Fig. 1) sediments have salt water percolation, groundwater from wells located in the tailings had relatively high salinity and was most likely composed of estuary and fresh water (Golder Associates).

Today the Juneau waterfront is built on rock fill from the A-J Mine and Douglas waterfront is adjacent to the former tailings deposits. One of Juneau's commercial areas is situated on the A-J rock dump and a permit has been issued to allow dredging for a boat harbor. In 1989, a Canadian mining company filed applications to reopen the A-J gold mine and resume mining operations. The company proposes to pump cyanide-treated tailings to an impoundment in a nearby mountain valley and construct a outfall pipe into Gastineau channel for excess

tailings water.

Gastineau Channel is ~20 km long and varies in width from 0.6 to 1.3 km., center channel depth is~ 35 to 40 m. The shoreline is generally steep-sided with rocky outcrops and localized deltas at the mouths of numerous creeks that empty into the channel. Freshwater inflow is minor compared to tidal volume. Tides follow the long axis of the channel and fluxuate to 7.6m.

The channel is a major recreational crabbing area for both tanner (Chionoecetes bairdi) and dungeness crab (Cancer magister) and supports pink salmon (Oncorhynchus gorbuscha), chum, (O.keta) and silver salmon (O.kisutch) roadside fisheries. Protected waters of the channel are the wintering area for numerous species of waterfowl including, scaup (Aythya affinis), scoters (Melanitta nigra, M.fusca,M.perspicillata) goldeneyes (Bucephala islandica, B.clangula) bufflehead (B.albeola) and harlequin ducks (Histrionicus histrionicus). Many other species of waterfowl and shorebirds move through the channel during spring and fall migration. Bald eagles (Haliaeetus leucocephalus) are very common residents and their nests are found along the Channel.

STUDY OBJECTIVES

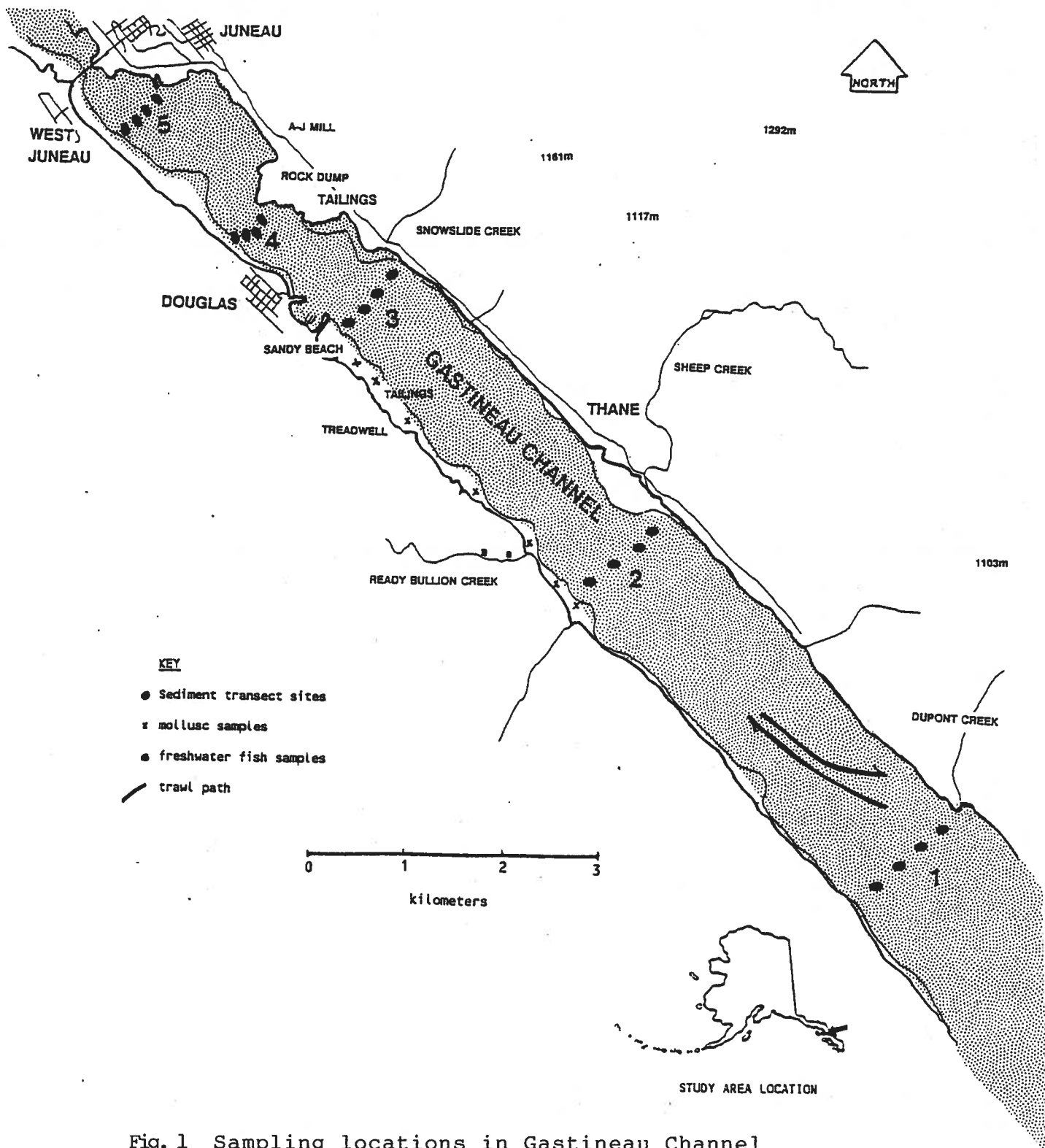
Objectives of this study were to (1) determine the concentration of potentially toxic metals in sediment from Gastineau Channel; (2) to determine concentrations of metals in resident biota of the channel; (3) to compare metal concentrations with data from other locations in southeast Alaska and NOAA National Status and Trends data; and (4) determine if concentrations present a risk to resident biota.

MATERIALS AND METHODS

Sediment Samples

Sediment samples were taken along five transects across Gastineau Channel from downtown Juneau to 12 km south of Juneau during 23 - 24 April 1991 (Fig.1). Stations for each transect were located near shore on both sides of the channel and half-way to mid-channel from each shore. Samples were collected using a 0.1 m² Smith McIntyre dredge. Between each grab, all traces of sediment were rinsed from the dredge using ambient seawater. At each station a stainless steel spoon was used to transfer and mix sediments. The spoon was also washed with ambient seawater between samples. All samples were mixed in a stainless steel pan, rinsed between stations with ambient seawater. Three grabs were taken at each station. These three samples were composited and homogenized. Each homogenized sample was split to form three duplicate samples that were placed in precleaned jars (I-Chem[®] 200 series, 125 ml) and refrigerated.

Biota Collection



Fish and shrimp were collected by a mid-channel trawl on April 25, 1991 (Fig.1) Blue mussels (Mytilus trossulus) and cockles (Clinocardium nuttallii) were collected at low tide from six locations in the vicinity of the former Treadwell Complex on Douglas Island on June 28, 1991. Freshwater fish, Dolly Varden (Salvelinus malma), and sculpins (family Cottidae), were collected between June 21 and 24, 1991, using minnow traps in Ready Bullion Creek which flows through the former Treadwell mine site. All fish samples were identified to species (except for sculpins and shrimp), weighed, measured, and wrapped in foil before freezing. Fish measurements and percent moisture (laboratory determined) are presented in Appendix A. Mussels and cockles were depurated for 12 hours in seawater, tissues were removed from shells using precleaned stainless steel knives and put into precleaned jars and frozen. All marine fish and mollusc tissue samples were composites of three or more individuals of the same species or genus. Two of the three freshwater fish samples were composites of six small sculpins, the third sample was an individual Dolly Varden. Gastineau Channel tissues were compared to previously collected samples from other locations for comparison.

Whole fish were analyzed in this study to focus the study on uptake of metals through the food chain rather than human health. Marine fish sampled were primarily bottom feeders - sole, flounder, and sculpin. Shrimp feed throughout the water column. Migratory species of fish such as salmon were avoided as not being representative of the channel.

Laboratory Analysis

All samples were sent to Research Triangle Institute (RTI), North Carolina, where they were homogenized and portions were freeze dried for determination of moisture content and subsequent acid digestion with nitric acid. Samples were digested using a CEM microwave oven. Graphite Furnace Atomic Absorption measurements were made using a Perkin-Elmer Zeeman 3030 atomic absorption spectrophotometer with an HGA-600 graphite furnace and an AS-60 autosampler. Inductively coupled plasma emission spectroscopy (ICP) measurements were made using a Leeman Labs Plasma Spec I sequential spectrometer. Results were expressed in ppm dry weight, wet weight data were also obtained.

Quality Assurance/Quality Control

The Quality Assurance (QA) program was conducted at Patuxent Analytical Control Facility (PACF) and reviewed Standard Reference Materials (SRM's), duplicates, spike recoveries, and procedural blanks to determine if lab data were acceptable. There were five duplicates per analyte, four sediment and one tissue sample. There were five procedural blanks. Sources of SRM's for this study included the National Institute of Standards and Technology and the National Research Council of Canada. Acceptable accuracy for percent recovery of metals in spiked

samples and SRM's by Atomic Absorption was 85 to 115%, by ICP measurements it was 80 to 120 % (U.S. Fish and Wildlife Service Criteria, Moore 1990). The PACF QA officer reviewed these data to ensure that they met U.S. Fish and Wildlife Service standards before they were sent to the investigator.

Metal digestions of sediments performed by RTI are incomplete, resulting in the release of some, but not all of the analyte. The metals released are those that would be readily available for release in an acidic environment and therefore be biologically available. Tissue sample digestions are complete, releasing all metals in this matrix.

Detection limits for different matrices and elements are found in Table 1.

Table 1. Maximum detection limits for matrices and elements tested from Gastineau Channel.^a

	<u>Metal Concentrations in (ppm)</u>						
	<u>As</u>	<u>Cd</u>	<u>Cu</u>	<u>Hg</u>	<u>Pb</u>	<u>Se</u>	<u>Zn</u>
Sediment, marine fish, shrimp	0.49	0.04	4.99	0.09	4.99	0.49	4.99
Molluscs, freshwater fish	0.4	0.05	2.0	0.2	0.2	0.3	3.0

^a Detection limits were slightly lower for some samples depending on sample volume.

Statistical Analysis

Statistical analysis was conducted using PC SAS. Logarithmic transformations were used to normalize all metals data. Equal and unequal variance t-tests were conducted to compare the Juneau shoreline sediment samples with the Douglas shoreline sediment samples for each analyte. Fixed effects analysis of variance and Duncan's Multiple Range Tests were conducted by analyte comparing the five transects and concentrations by sample matrix. Means presented are arithmetic means.

Table 2. Mean metal concentrations (ppm, dry weight) for each sediment sampling station in Gastineau Channel.

ANALYTE	TRANSECT	DOUGLAS	MID	MID	JUNEAU
As	5	12.9	23.9	12.9	25.9
	4	17.8	25.3	27.7	35.4
	3	19.8	51.0	29.9	47.5
	2	17.2	19.1	19.7	18.3
	1	9.28	9.72	12.48	6.69
	$\bar{X} =$				
Cd	5	0.316	0.509	0.362	0.544
	4	0.501	0.676	0.913	0.960
	3	0.433	1.313	0.803	3.053
	2	0.349	0.247	0.230	0.267
	1	0.089	0.090	0.160	0.264
	$\bar{X} =$				
Cu	5	65.87	72.17	45.13	74.37
	4	49.93	48.10	53.60	49.33
	3	70.40	58.90	70.17	52.60
	2	48.77	54.47	58.30	48.47
	1	25.67	26.07	41.17	21.77
	$\bar{X} =$				
Hg	5	0.122	0.249	0.182	0.376
	4	0.166	0.317	0.117	0.109
	3	0.326	0.143	0.267	0.099
	2	0.347	0.300	0.346	0.160
	1	0.221	0.137	0.355	0.098
	$\bar{X} =$				
Pb	5	37.4	71.3	43.6	80.5
	4	52.7	53.1	70.5	70.5
	3	58.1	66.0	81.7	71.3
	2	62.2	56.2	60.5	37.0
	1	30.9	25.3	43.0	19.0
	$\bar{X} =$				
Se	5	0.613	1.31	0.85	1.16
	4	0.923	0.870	0.935	0.880
	3	1.06	1.22	1.19	0.78
	2	0.947	1.04	0.99	1.13
	1	0.524	0.693	0.760	1.040
	$\bar{X} =$				
Zn	5	98.7	151	94.6	156
	4	115	124	136	143
	3	120	181	165	191
	2	109	135	127	109
	1	73.9	75.5	107.6	60.9
	$\bar{X} =$				

Table 3. Metal concentrations in ppm dry weight in sediments from Gastineau Channel, Juneau, Alaska.

	As	Cd	Cu	Hg	Pb	Se	Zn
X (n=20)	22.12	0.60	53.76	0.22	54.54	0.95	123.55
range	5.83- 79.20	0.05-3.96	19.40- 103.00	0.09-0.55	7.06- 148.00	0.48-1.38	25.40- 242.00
StdDev	±11.85	±0.66	±14.18	±0.10	±18.16	±0.21	±34.74
75% ^a	27.40	0.68	60.15	0.29	68.05	1.11	151.50
ER-L ^b	33.00	5.00	67.00	0.15	35.00	---	120.00

^a 75% value is the upper one-quarter (25%) of all observations.

^b ER-L = low effects range concentrations from the NOAA Status and Trends Program (Long and Morgan 1990).

RESULTS

Sediment analysis

Sediment metal concentrations for Gastineau Channel sediments are presented in Table 2. Percent coefficient of variation for the means of each of the metals were: As, 62; Cd, 115; Cu, 33; Hg, 52; Pb, 43; Se, 26; and Zn, 32. The high coefficient of variation for these means indicated a larger variability in some metal concentrations than others on a per-sample basis.

Examining the upper 25 percent of the concentrations reflects the pattern of elevated mean concentrations of arsenic, copper, lead, and zinc (Table 3).

Metal concentrations in sediments along the Juneau shore (n=5) were compared to the locations along the Douglas shore (n=5). The Juneau shore sediments did not significantly differ from concentrations from the Douglas shore (Table 4). Metal concentrations from near-shore locations did not differ from mid-channel locations ($P < .05$). Comparing concentrations for each of the five transects revealed the transect closest to the mouth of the channel (background) had the significantly lower concentrations for copper. There were no clear statistical differences evident among the other transects.

Isograms were developed for metal concentrations in the channel. Some clear patterns of metal distributions are indicated in figure 2.

Comparison with Alaskan clean locations indicates that Gastineau Channel samples were higher in arsenic, copper, mercury, and lead (Table 4). Zinc concentrations were half of those reported in sediments from Lutak Inlet (Robinson-Wilson and Malinkey unpub. data). Gastineau Channel sediments had similar lead concentrations to Klag Bay, an area with old tailings from a lead mine (Robinson-Wilson, unpub. data). Zinc concentrations from Gastineau Channel were much higher than Klag Bay concentrations.

CONT. w/ TEXT

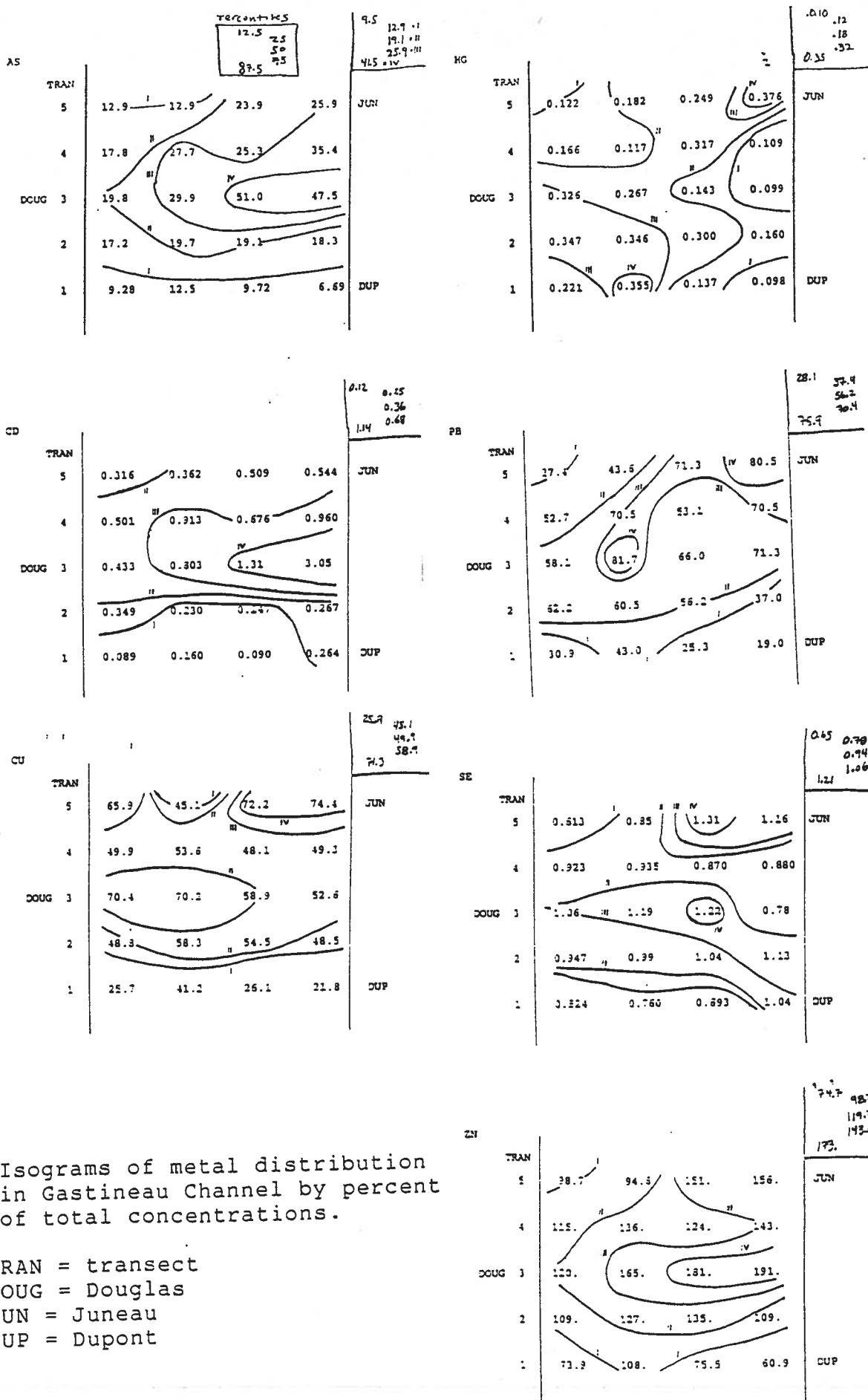


Table 4. Comparison of mean metal concentrations (ppm dry weight) in sediments along the Juneau and Douglas shorelines.

	As	Cd	Cu	Hg	Pb	Se	Zn
Juneau (n=5)	26.7	1.0	49.3	0.17	55.6	0.99	132.0
Douglas (n=5)	15.4	0.34	52.1	0.23	48.3	0.81	103.2

Tissue analysis

Marine fish species analyzed for metal residues were, rock sole (Lepidopsetta bilineata), flathead sole (Hippoglossoides elassodon), yellowfin sole (Limanda aspera), starry flounder (Platichthys stellatus), shortfin eelpout (Lycodes brevipes), and sculpin (family Cottidae) which were not identified to species,. A composite of unidentified shrimp species was also collected .

There are very few whole fish data for comparison of metal residues. Comparison with metal residues from Pacific herring (Clupea harengus pallasii) from Alaska (Hall et al. 1978) is displayed in Table 6. Gastineau Channel fish, (n=9) had higher whole body concentrations for copper, lead, selenium, and zinc. No comparative data was found for whole shrimp; data from cleaned, deveined, and deheaded Alaskan sidestripe shrimp (Pandalopsis dispar) (Hall et al. 1978) was included in Table 4 for gross comparison.

Molluscs from the Treadwell Complex tailings had elevated mean metal concentrations for lead and zinc when compared to metal concentrations in blue mussels from Hawk Inlet (Robinson-Wilson, unpub.). Zinc was the only metal that exceeded concentrations from Boca de Quadra mussels. Both Hawk Inlet and Boca de Quadra were without any anthropogenic sources of contamination when sampled in 1986 and 1987. Copper concentrations were similar to other Southeast Alaska locations. Mussel metal data from Nahku Bay (Robinson-Wilson and Malinkey, unpub. data) were much higher than concentrations reported in this study.

There were no significant differences in metal concentrations between mussels and cockles ($P>0.05$) (Table 7).

There were no whole freshwater fish dry weight residue data from

Table 5. Metal concentrations (ppm, dry weight) in southeast Alaska sediments

	As	Cd	Cu	Hg	Pb	Se	Zn
Gastineau Channel ^a	21.75	0.59	51.31	0.22	53.49	0.94	121.71
Klag Bay ^b	193.50 ± 50	1.8 ± 0.2	-----	1.7 ± 0.2	48.0 ± 0.2	-----	70.0 ± 5.7
Klag Bay Control ^b	66.0 ± 8	0.6 ± 0.4	-----	0.2 ± 0.1	3.0 ± 0.3	-----	7.0 ± 0.4
Nahku Bay (ADEC) ^c	3.08	0.347	-----	-----	32.5	0.13(U)	-----
Nahku Bay (NOAA) ^d	1.66	1.51	-----	-----	56.40	1.26	-----
Lutak Inlet (ADEC) ^e	5.0	0.17(U)	-----	-----	9.66	0.13(U)	-----
Lutak Inlet (ADEC) ^e (Max. Conc.)	6.66	0.59	-----	-----	34.5	0.14	-----
Lutak Inlet (NOAA) ^d	1.51	1.10	-----	-----	17.6	0.14	-----
Lutak Inlet (USFWS) ^f	-----	0.9	9.0	0.05	37.0	-----	257.0

^a This study, mean value (n=20) for each analyte.

^b USFWS, unpublished data from 1986. Control located approximately 1.5 km south of Klag Bay.

^c ADEC,

^d NOAA, 1991. Second Summary of Data on chemical Contaminants in Sediments from the National Status and Trends Program. NOAA Tech. Mem. NOS OPM 59.

^e ADEC, Lutak Inlet Sampling Project Summary, 1990.

^f Unpublished report, E. Robinson-Wilson and, G. Malinkey.

Table 6. Metal concentrations (ppm, dry weight) in whole fish from Gastineau Channel, Klag Bay, and Gulf of Alaska.

	As	Cd	Cu	Hg	Pb	Se	Zn
R sole ^{a1} (n = 1)	3.76	0.05	4.04	0.21	0.90	0.90	76.4
F sole ^{a2} (n = 3)	4.49	0.09	4.27	0.12	4.58	1.15	79.5
Starry ^{a3} flounder (n = 2)	2.55	0.14	3.65	.036	1.74	1.13	73.7
yfsole ^{a4} (n = 1)	4.95	0.24	2.99	0.17	1.08	1.34	111.0
sculpin ^{a5} spp. (n = 1)	1.85	0.06	5.42	0.10	0.65	0.97	40.7
eelpout ^{a6} (n = 1)	4.45	0.20	9.52	0.29	3.53	2.18	89.3
X fish ^a (n = 9)	3.73	0.15	4.31	0.21	2.60	1.48	88.09
Pac. herring ^{b7}	2.439	0.128	1.212	0.260	1.082	0.761	14.3
yf sole ^c (n=4)	10.575	0.60	----	4.65	10.4	----	80.5
Pacific tomcod ^{c8} (n=4)	13.525	0	----	6.025	1.175	----	51.1
Kelp greenling ^{c9} (n=4) ^b	7.0	0	----	5.775	5.4	----	68.725

^a Gastineau Channel

^b Hall, R.A., E.G. Zook, and G.M. Meaburn. 1978. National Marine Fisheries Service Survey of Trace Elements in the Fishery Resource. NOAA Tech. Rep. NMFS SSRF - 721.

^c Klag Bay (Robinson-Wilson, unpub. data)

¹ rock sole (Lepidopsetta bilineata)
composite of 2 fish

⁵ sculpin species (family Cottidae)
composite of 7 fish

² flathead sole (Hippoglossoides elassodon)
two composites of 5 fish each, 1 composite
of 2 fish

⁶ shortfin eelpout (Lycodes brevipes)
composite of 15 fish

³ starry flounder (Platichthys stellatus)
two composites of 3 fish each

⁷ Pacific herring (Clupea harrenqus)

⁴ yellowfin sole (Limanda aspera)
composite of 2 fish

⁸ Pacific tomcod (Microgadus proximus)

⁹ Kelp greenling (Hexagrammos decagrammus)

Table 7. Metal concentrations (ppm dry wt. means. \pm SD) in blue mussels (Mytilus trossulus) from locations throughout Southeast Alaska.

	As	Cd	Cu	Hg	Pb	Zn
Douglas Is. (n=6)	10.57 \pm 1.81	2.53 \pm 0.73	8.90 \pm 0.81	<0.2(U)	1.65 \pm 0.49	112.03 \pm 13.77
Silver Bay ^a (n=9)	-----	-----	9.178 \pm 3.079	0.216 \pm 0.022	0.796 \pm 0.260	72.889 \pm 14.598
Klag Bay ^a (n=12)	-----	-----	11.75 \pm 3.406	0.229 \pm 0.193	5.188 \pm 5.843	80.917 \pm 12.638
Hawk Inlet ^a (n=15)	-----	-----	10.047 \pm 1.520	0.138 \pm 0.022	0.745 \pm 0.298	98.733 \pm 1.52
Duncan Canal ^a (n=18)	-----	-----	7.528 \pm 3.898	0.132 \pm 0.018	2.128 \pm 0.242	64.0 \pm 24.807
Boca de Quadra ^a (n=21)	-----	-----	8.514 \pm 7.087	0.661 \pm 0.973	2.271 \pm 0.598	68.048 \pm 7.087
Nahku Bay ^b	-----	4.7/23.5 ^c	9.5/47.5 ^c	U	27/135 ^c	96/480 ^c
Cann Creek ^e	12.30 \pm 0.58	7.6 \pm 0.83	6.87 \pm 0.42	0.08 \pm 0.01	0.57 \pm 0.38	70.33 \pm 8.62
Douglas Island cockle ^e	9.45 \pm 1.14	0.31 \pm 0.18	7.44 \pm 2.86 ^c	<0.2(u)	2.13 \pm 0.54 ^c	100.58 \pm 16.91

^a Unpublished USFWS data from 1986, 1987 sampling.

^b Unpublished report E. Robinson-Wilson and G. Malinkey

^c Approximate dry weight calculations = wet weight \times 3

^d Clinocardium nuttali

^e Unpublished USFS data, 1993 sampling on Chichagof Island

Alaskan waters available for comparison. There were however, whole wet weight data available for some Alaskan species. Wet weight concentrations can be converted to a dry weight value by multiplying by a factor of three. Freshwater fish (Dolly Varden and sculpin species) from Ready Bullion Creek had concentrations of arsenic that were three to five times higher than fish tissue concentrations from other Alaskan locations; cadmium concentrations were comparable to the calculated dry weight values from Neka River sampling (Table 8). A lead concentration of 14.7 ppm in Dolly Varden was exceedingly high. Copper and zinc concentrations were much higher than those found in fish sampled from the Neka River in 1992 by the Alaska Department of Environmental Conservation (Table 8).

DISCUSSION

SEDIMENT ANALYSIS

Because the Juneau area is heavily mineralized, it was expected that natural sediments would be elevated in metals. Data from Gold Creek, however, the major source of freshwater to Gastineau Channel, does not have elevated metal concentrations (H. Seitz, USGS, pers. comm.). Mercury, lead, and zinc concentrations were elevated above what would be considered the low effects range (ER-L) concentration that was developed in the NOAA Status and Trends Program (Long and Morgan 1990). Because there are no national sediment criteria at this time, the NS&T concentrations were used as comparison values for these data. Arsenic and copper concentrations were close to but below the ER-L concentrations. Cadmium concentrations were more than five times lower than the ER-L.

Contaminated sediments may be directly toxic to aquatic life or can be a source of contaminants for bioaccumulation in the food chain (Ingersoll 1991). Based on metal concentrations detected in this study, Gastineau Channel sediments are contaminated with some metals. Selenium and cadmium were found at concentrations that represent a "clean" ranking based on the NS&T program. Cadmium was not at concentrations that have been reported to cause toxicity to marine organisms. Moderate toxicity occurred to an amphipod with mean cadmium concentrations at 0.5 ppm in sediments from San Francisco Bay, California (McGreer 1979, p.18 in Long and Morgan 1990). Lee and Mariani (1977 in Long and Morgan 1990) reported zero percent mortality to an estuarine grass shrimp, Palaemonetes pugio, in Rhode Island with cadmium concentrations at <0.5 ppm.

Table 8. Metal concentrations (ppm) in whole freshwater fish.

Species		As	Cd	Cu	Hg	Pb	Zn
Rainbow trout ^a (<i>Salmo gairdneri</i>)	wet wt. ^b dry wt. ^b	0.10 - 0.16 (0.30 - 0.48)	<0.05 - 0.07 (0.15 - 0.21)	----	0.05 - 0.06 (0.15 - 0.18)	----	----
Brown trout ^a (<i>Salmo trutta</i>)	wet wt. ^b dry wt. ^b	<0.05 (<0.15)	<0.05	----	0.07 - 0.21 (0.21 - 0.63)	0.19 - 0.20 (0.57 - 0.6)	----
Lake trout ^a (<i>Salvelinus namaycush</i>)	wet wt. ^b dry wt. ^b	0.06 - 0.11 (0.18 - 0.33)	<0.05 (<0.15)	----	0.18 - 0.23 (0.54 - 0.69)	---	----
Arctic grayling ^a (<i>Thymallus arcticus</i>)	wet wt. ^b dry wt. ^b	<0.05 (<0.15)	ND - <0.05 (<0.15)	----	0.05 - 0.06	0.19 - 0.23 (0.57 - 0.69)	----
Dolly Varden ^c (<i>S. malma</i>)	wet wt. ^b dry wt. ^b	<1.0(U) ----	0.41 (1.23)	0.6 (1.8)	0.03 (0.9)	0.05(U) ----	5.29 (15.87)
Dolly Varden ^d (<i>Salvelinus malma</i>)	dry wt.	1.9	1.38	6.63	0.414	14.7	125
Sculpin species ^d	dry wt.	.78	0.33	3.945	0.5	3.11	91.15

^a Walsh, D.F., B.L. Berger, and J.R. Bean. 1977. Residues in fish, wildlife, and estuaries. Mercury, arsenic, lead, cadmium, and selenium residues in fish, 1971-1973. National Pesticide Monitoring Program. Pesticide Monitoring Journal 2(1):5-34. Sample sources: Arctic grayling - Chena River; Lake, Rainbow trout - Kenai River; Brown trout - Rio Grande, CO.

^b Approximate dry weight calculated from wet weight x 3.

^c Neka River, Alaska. ADEC, Neka Bay, Port Frederick Fish Kill Investigation Final Report. August 1992.

^d Ready Bullion Creek, Douglas, Alaska.

The range of selenium in ocean sediments was reported at 0.34 to 4.8 ppm by de Goeij et al. 1974 (in Eisler 1985). The range in this study was 0.48 to 1.38 ppm.

Arsenic concentrations at 22.8 ppm were toxic to bivalve larvae in San Francisco Bay (DeWitt et al. 1988 in Long and Morgan 1990), and 20 ppm is the high contamination level for dredge material in New England (Bahnick et al. 1981 in Long and Morgan 1990). Arsenic concentrations in this study ranged from 5.8 to 79.2 ppm.

The lower 10 percentile of copper data from the NS&T program is approximately 70 ppm. Most sediments were not toxic until copper concentrations exceeded 110 ppm (Long and Morgan 1990). Copper concentrations in Gastineau Channel ranged from 20 to 103 ppm, concentrations considered non-toxic in most toxicity studies.

Mercury was reported (Eisler 1987) to be the most toxic trace metal to aquatic organisms, with lethal concentrations ranging from 0.1 to 2.0 ppm. Mercury concentrations detected in this study ranged from 0.098 to 0.54 ppm. Toxicity of mercury is increased in the presence of lead and zinc, both of which were detected in Gastineau Channel at concentrations that could cause chronic effects to some marine organisms.

Marine organisms may be more resistant to the effects of lead than freshwater species (Eisler 1988a). At 35 and 42 ppm benthos diversity in Norwegian fjords and depressed benthos species richness in Massachusetts Bay were reported (Rygg 1985, Gilbert et al. 1976 in Long and Morgan 1990). Effects were usually observed when lead concentrations were 110 ppm or greater (Long and Morgan 1990). Lead concentrations from Gastineau Channel ranged from 7 to 148 ppm with a mean of 53.5 ppm exceeding the ER-L of 35 ppm.

Data summarized by Long and Morgan (1990) for the NS&T program suggest that chronic effects occur at zinc concentrations of about 50 to 125 ppm. At 117 ppm Massachusetts Bay had low benthos species richness (Gilbert et al. 1976); zinc concentrations at 195 and 211 ppm were moderately toxic to the amphipod, Rhepoxynius abronius, in two Washington state studies (DeWitt et al. 1988, Tetra Tech 1985 in Long and Morgan 1990). Chronic effects to marine organisms could occur at the 25.4 to 242 ppm range found in Gastineau Channel.

The lowest concentrations found near the mouth of the channel may be considered baseline, but the higher concentrations represent contributions from human activities such as mining, the municipal sewer outfall, and urban non-point source pollution. Water quality will be very different at the sewer outfall, due to fresh water input. For example, pH could be more acidic making metals in this area more available in the water column.

Mean concentrations of lead, mercury and zinc in Gastineau Channel were comparable to concentrations found in sediments from South Puget Sound (Long and Morgan 1990), an area with pollution problems. In comparison to Naku Inlet, an unpolluted water body approximately 80

miles north of Juneau, Gastineau Channel sediment metal concentrations exceed concentrations for all metals except zinc (Robinson-Wilson and Malinkey, unpub.rep.). None of the metal concentrations in sediments from Gastineau Channel reported in this study indicate a severe problem, however, these concentrations do indicate a stressed system that could be worsened with additional input of metals.

The isograms (fig. 2) show that the highest concentrations of most metals appeared to be localized - across from, Sandy Beach and the former Treadwell Mine on Douglas Island - a former tailings deposition site, downtown Juneau, and Snowslide Creek on the Juneau side. The concentrations from transect 5 on the Juneau side of the Channel can most likely be attributed to both present day urban activities and the extensive tailings dumping that occurred during the early 1900's. The upland area near Snowslide Creek is the site of the former city landfill and is the location for deposit of sludge from the municipal sewer system.

ADD DISCUSSION OF ISOGRAMS, POSSIBLE METAL SOURCES, DATA FROM ADEC ON SEWAGE SLUDGE.

TISSUE ANALYSIS

ADD DISCUSSION OF TABLE 6,7,8.

Examining the data by species indicates that shrimp accumulated the highest concentrations of arsenic, cadmium, and copper. The copper concentration was 72.0 ppm in the composite shrimp sample in this study (Table 9). Bryan (1968) reported 30 to 32 ppm in whole shrimp from Great Britain; an Oregon study reported a mean concentration of 18.8 and a maximum of 26 ppm in pink shrimp (Pandalus jordani), (Cutshall and Holton 1972 in Jenkins 1980). Lead concentrations in that study ranged from 1.3 to 3.5 ppm, lead was measured at 1.45 ppm in shrimp from the channel.

Table 9. Metal concentrations (ppm, dry weight) in shrimp.

	As	Cd	Cu	Hg	Pb	Se	Zn
Gastineau Channel (<i>Pandalus</i> spp., <i>Pandalopsis dispar</i>) ^a	30.5	0.87	72.0	0.14	1.445	1.63	65.7
Gulf of Alaska (<i>Pandalopsis dispar</i>) ^b	4.71	0.09	5.63	0.04	0.65	0.34	13.48

^a Whole shrimp

^b Cleaned, deveined, deheaded (Hall et al. 1978).

Marine organisms normally contain arsenic residues of several to more than 100 ppm dry weight (Lunde 1977). Arsenic concentrations (dry weight) in shrimp were 0.6 ppm and 3.8 ppm (Sims and Presley 1976), and 16.0 ppm (Burton 1974). Because arsenic occurs as arsenobetaine in marine organisms (Eisler 1988b), this metal does not present a problem in the concentrations measured in channel organisms. However, limited data are available on its interactions with other chemicals, therefore synergistic effects are unknown.

Metal concentrations in molluscs from the Treadwell/Sandy Beach area on Douglas Island were comparable to concentrations of arsenic, mercury, lead, copper, and zinc from molluscs from two known areas of heavy pollution in Washington state - Commencement Bay and South Puget Sound (Long and Morgan 1990). The concentrations detected in blue mussels in Gastineau Channel could contribute to metal contamination in sea ducks that are winter residents because they are the major food item for these birds. Molluscs may also be an agent for transfer of metals from the sediment to other biota.

In summary, Gastineau Channel has had metals leaching from tailings for 75 years or more in combination with urban non-point source pollution. This study appears to demonstrate that metals in sediments may be bioavailable to various marine organisms within the short, direct, shellfish to fish food chain examined. Proposals for Gastineau Channel to receive metal-bearing effluent from future mining activity should be carefully considered with respect to these data.

LITERATURE CITED

- Bahnick, D.A., W.A. Swenson, T.P. Markee, D.J. Call, C.A. Anderson, and R.T. Morris. 1981. Development of bioassay procedures for defining pollution of harbor sediments. EPA-600/S3-81-025. Duluth, MN. U.S. Environmental Protection Agency. 4 pp.
- Brooks, R.R., and D. Rumsey. 1974. Heavy metals in some New Zealand commercial fishes. N.Z. Journ. Mar. & Freshwat. Res. 8(1): 155-66.
- Bryan, G.W. 1968. Concentrations of zinc and copper in tissues of decapod crustaceans. J. Mar. Biol. Assn. U.K. 48:303-321.
- Cutshall, N., and R. Holton. 1972. Metal analysis in IDOE baseline samples. In: IDOE Workshop on Baseline Studies of Pollutants in Marine Environment. Brookhaven Nat. Lab. pp.67-82. May 1972.
- DeWitt, T.H., G.R. Ditsworth, and R.C. Swartz. 1988. Effects of natural sediment features on survival of the phoxocephalid amphipod, Rhepoxynius abronius. Mar. Environ. Res. 25: 99-124.
- Eisler, R. 1985. Selenium hazards to fish, wildlife, and invertebrates: a synoptic review. Biolo. Rep. 85(1.5) Laurel, MD: USFWS, DOI. 57 pp.
- Eisler, R. 1987. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. Biolo Rep. 85(1.10). Laurel, MD: USFWS, DOI. 90 pp.
- Eisler, R. 1988a. Lead hazards to fish, wildlife, and invertebrates: a synoptic review. Biolo. Rep. 85(1.14). Laurel, MD: USFWS, DOI. 134 pp.
- Eisler, R. 1988b. Arsenic hazards to fish, wildlife, and invertebrates: a synoptic review. Biol. Rep. No. 85(1.12). Laurel, MD: USFWS, DOI. 92 pp.
- Gilbert, T., A. Clay, and C.A. Karp. 1976. Distribution of polluted materials in Massachusetts Bay. Boston, MA: New England Aquarium. 173 pp.
- Golder Associates, Inc. Dec. 1987. Environmental audit investigation of A.J. Mine Rock Dump, Juneau, Alaska. Submitted to Bank of CA. Seattle, WA.
- Greig, R.A., and D.R. Wenzloff. 1977. Trace metals in finfish from the New York Bight and Long Island Sound. Marine. Pollut. Bull. 8(9): 198-200.
- Hall, R.A., E.G. Zook, and G.M. Meaburn. 1978. National Marine Fisheries Service Survey of Trace Elements in the Fishery Resource. NOAA Tech. Rep. NMFS SSRF - 721.

- Ingersoll, C. 1991. Sediment toxicity and bioaccumulation testing. ASTM Std. News 19(4):28-33.
- Jenkins, D.W. 1980. Biological Monitoring of Toxic Trace Metals. Vol. 2. Toxic Trace Metals in Plants and Animals of the World. Part I - II.
- Lee, G.F. and G.M. Mariani. 1977. Evaluation of the significance of waterway sediment-associated contaminants on water quality at the dredged material disposal site. In: Aquatic Toxicology and Hazard Evaluation. F.L. Mayer and J.L. Hamelink, Eds. ASTM STP 634. Philadelphia, PA: Amer. Soc. for Testing and Materials. pp. 196-213.
- Long, E.R. and L.G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. NOAA Tech. Memo. NOS OMA 52. Seattle, WA. 175 pp.
- Lunde, G. 1977. Occurrence and transformation of arsenic in the marine environment. Environ. Health Perspec. 19(47-52).
- McDermott, D.J., G.V. Alexander, D.R. Young and A.J. Mearns. 1976. Metal contamination of flatfish around a large submarine outfall. J. Water Pollut. Control Fed. 48(8):1913-1916.
- McGreer, E.R. 1979. Sublethal effects of heavy metal contaminated sediments on the bivalve Macoma balthica (L.). Mar. Poll. Bull. 10(9): 259-262.
- Moore, J. editor. 1990. PACF Reference Manual. June 1990. PACF, USFWS, Laurel, MD.
- NOAA. 1987. A summary of selected data on chemical contaminants in tissues collected during 1984, 1985, and 1986. NOAA Tech. Memo. NOS OMA 38.
- Phillips, D.J.H. 1977. The use of biological indicator organisms to monitor trace metal pollution in marine and estuarine environments - a review. Environmental Pollution 12:281-317.
- Robertson, D.E., L.A. Rancitelli, J.C. Langford and R.W. Perkins. 1972. Battelle-Northwest contribution to the IDOE base-line study. In: Workshop on Baseline Studies of Pollutants in Marine Environment. Brookhaven Nat. Lab. pp.24-26. May 1972.
- Robinson-Wilson, E.F., and G. Malinkey. October 1985 (unpub. mss.). Trace metals contamination at an ore loading facility in Skagway, Alaska. USFWS and ADEC, Juneau, Alaska. 17 pp.
- Rygg, B. 1985. Effects of sediment copper on benthic fauna. Mar. Ecol. Prog. Series 25: 83-89.
- Sims, R.R. Jr., and B.J. Presley. 1976. Heavy metal concentrations in organisms from an actively dredged Texas bay. Bull. Environ. Contam & Toxicol. 16:520-527.

Stone, D. and B. Stone. 1980. Hard Rock Gold, the Story of the Great Mines that were the Heartbeat of Juneau. Seattle, WA. Vanguard Press.

Tetra Tech, Inc. 1985. Commencement Bay nearshore/tideflats remedial investigation. Vol.3. Appendices I-V, TC-3752, 371 pp. Vol.4. Appendices VI-XV. 556pp. Bellevue, WA: Tetra Tech, Inc.

Walsh, D.F., B.L. Berger, and J.R. Bean. 1977. Residues in fish, wildlife, and estuaries. Mercury, arsenic, lead, cadmium, and selenium residues in fish, 1971-1973. National Pesticide Monitoring Program. Pesticide Monitor. J. 2(1):5-34.

Appendix A

Fish samples from Gastineau Channel and Ready Buillion Creek, 1991 -
number in composite sample, percent moisture and length.

Sample Number	Number Fish	Species	Percent Moisture	Total Length (cm) Min.	Max.	\bar{x}
<u>Gastineau Channel</u>						
T01	2	RS	78.2	10.8	30.3	---
T02	2	FS	78.4	15.2	10.1	---
T05	7	SC	81.3	9.5	22	12.8
T06A	5	FS	78.4			
				14	32	20.9
T06B	5	FS	78.8			
T07A	2	YF	76.4	29	30	---
T09A	3	SF	80.5			
				35	38	36.3
T09B	3	SF	78.1			
T10	15	EP	81.1	14	23	17.5
T13	>50	SH	75.6	---	---	---
<u>Ready Bullion Creek</u>						
T01	1	DV	75.7	13.9 ^a	---	---
T02	6	SC	70.2	6.0 ^a	8.7	6.9
T03	7	SC	66.3	6.0 ^a	9.1	7.1

RS = rock sole

SC = sculpin species

FS = flathead sole

EP = shortfin eelpout

YS = yellowfin sole

SH = shrimp species